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TECHNICAL REPORT AFATL-TR-74-70

PLASTIC FRANGIBLE PROJECTILE

GUN FUNCTION TEST

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GUNS AND ROCKETS BRANCH
GUNS AND ROCKETS DIVISION

MARCH 1974

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AIR FORCE ARMAMENT LABORATORY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A test was conducted to determine how the plastic frangible cartridge assembly would function in an automatic aircraft gun environment over the temperature spectrum (i.e., +160°F, ambient, -65°F). Two 20mm aircraft guns (M61A1 six barrel Gatling and M39 single barrel revolver) were used. The projectile presented no problems so far as feed and gun function are concerned. Premature projectile breakups occurring at the high temperature extreme and at ambient conditions appear to be the result of an inadequate bond between the projectile tip and body, coupled with a reduced elastic modulus.

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PREFACE

This technical report is based on an analysis of a test performed as Armament Development Test Center (ADTC) Mission 1039, 18 March 1974.

This technical report has been reviewed and is approved.

DALE M. DAVIS
Director, Guns and Rockets Division

INTRODUCTION

A program was established to produce a non-ricocheting target practice projectile for aerial cannons. To meet this objective, the frangible projectile was conceived, embodying a new and radical design of target practice projectiles (Figure 1). The outer body is made of molded plastic, while the inner body is made up of steel washers or platelets (Figure 2). This design was established after considering the applied loads, as well as for economy and simplicity. During initial acceleration, the bullet is subjected to an axial compressive setback force of about 120,000g. As it travels through the barrel, it attains a high spin velocity (120,000rpm) with an attendant centrifugal force applied to the sides of the projectile. The design of the bullet permits it to easily handle these loads; however, upon impact, the relatively weak plastic skin, in conjunction with an instantaneous unbalanced loading at impact, causes the skin to rupture and scatter the washers. The washers, because of their relatively low energy (available kinetic energy divided by the number of washers per projectile) and their low sectional density and high drag factor, cannot travel as far as an intact deflected bullet. (See Figures 3 and 4)

Currently, the USAF has a very limited number of strafing test ranges for the 20mm machine gun. This is because a large safety "fan" is required behind the target area to contain long ricochets. The development of the 25mm and 30mm aircraft cannon with their larger projectiles at higher velocities will increase the requirement for larger safety fans (which are made up of extremely valuable real estate). The development of a frangible projectile would obviate this requirement, since with a frangible bullet, the hazards of long ricochets become almost negligible. Thus, smaller ranges would become useable despite an increasing surrounding population density. In conjunction with this, a consequent decrease in scheduling in current ranges, as well as a decrease in requirement for new land for larger ranges, would occur.

Another important factor is aircraft safety during air/ground gunnery practice. A review of aircraft accident/incident reports from the Office of Safety (TAC Headquarters) indicates that the problem of aircraft damage due to collision with ricocheting projectiles is continuing at a rate of 30 incidents per year.

This program demonstrated the initial feasibility of the concept. The next step was to test the projectile and determine its shortcomings in order to assure a better second generation projectile.

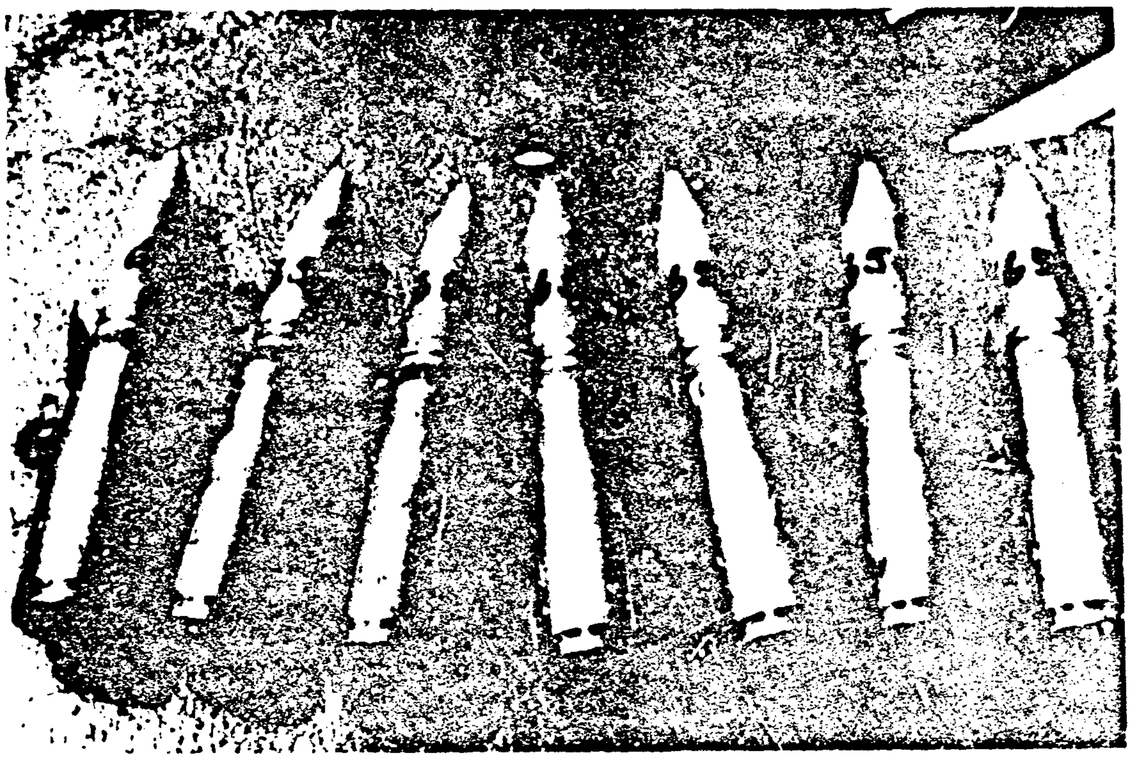

Figure 1. Belted Plastic Frangible Cartridges

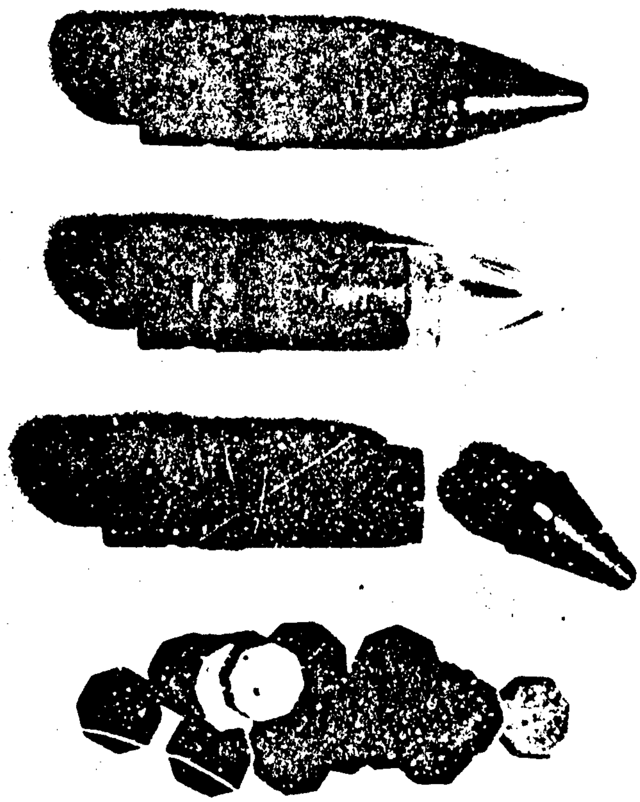

Figure 2. 20mm Plastic Frangible Projectile

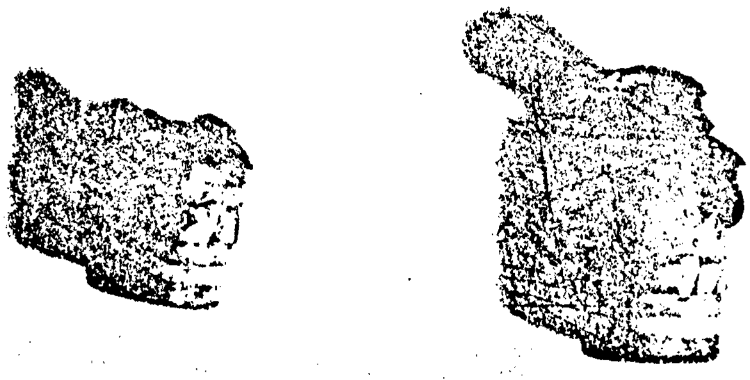

Figure 3. M55 A2 TP Projectiles After Impact
On Soft Sand At 45° Angle Obliquity

Figure 4. Plastic Frangible Projectiles After Impact On Soft Sand At 45° Angle Obliquity

TEST OBJECTIVE

The objective of the test discussed in this report was to determine how the plastic frangible cartridge assembly would function in an automatic aircraft gun environment over the temperature spectrum (i.e., +160°F, ambient, -65°F). Other parameters checked included the projectile velocity, and the projectile integrity in flight and after impact on the gun range butts.

The purpose of this test was to determine what improvements were needed in the projectile, what the apparent deficiencies were in the projectile, and what could be done to improve the performence of the projectile.

TEST EQUIPMENT AND CONDITIONS

Two different 20mm aircraft guns were used to test the projectiles: an M61A1 six-barrel Gatling gun and a single barrel revolver type M39 gun. The latter is noted for its exceptionally harsh treatment of ammunition. The test schematic is shown in Figure 5.

Lumaline velocity screens were set up. These screens were wired to recording equipment which recorded the projectile number, its velocity, the average velocity of the burst, and the rate of fire of the gun. The Lumaline screens were changed after the tests with the M61A1 gun (before the M39 gun test).

A target cloth was set up at 50 yards to record the spread of the projectiles.

The butts consisted of a large enclosed reinforced concrete shelter, open on one side. Sand was banked at about a 45° angle.

The projectiles were about 3 months old, i.e., the plastic (nylon 6/12, 43% glass reinforced) had sufficient time to absorb moisture and reach equilibrium. Twenty rounds were conditioned at -65°F for 4 hours and 20 rounds were conditioned at +160°F for 4 hours. The remaining 20 rounds were fired at ambient conditions (+70°F). Rounds were taken from the conditioning facility (fuze test) in an insulated box to the firing range, inserted in the feed chute, and fired. The elapsed time was approximately 12 minutes. X-ray photos of each projectile were examined prior to testing. Before the plastic frangible cartridges were fired in each gun, a control burst of standard M55A2 target practice (TP) projectiles were fired to assure that instrumentation was working properly.

In many cases the velocities of the projectiles could not be measured. This is indicated by dash lines in the velocity column on Tables 1 to 9.

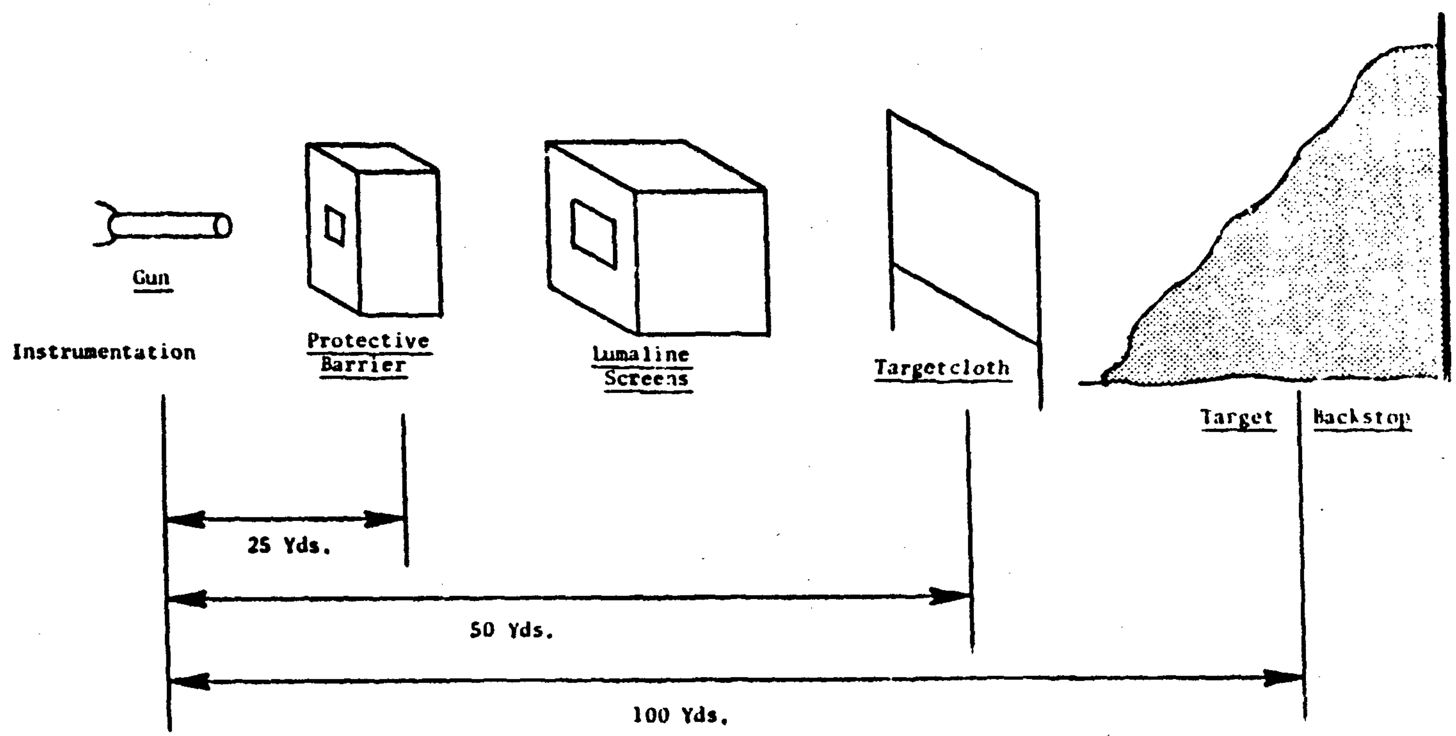

Figure 5. Test Schematic

TABLE 1. M61A1 GUN WITH M55A2 PROJECTILE AT +70°F (FIRST TEST)	
ROUND NO.	VELOCITY, ft/sec
1	3305
2	3255
3	3279
4	3273
5	3244

Remarks -
Gun Driving Voltage Circuit Breaker Functioned and Gun Stopped
Gun Rate:
434 rounds/minute
Average Velocity 3271 ft/sec

TABLE 2. M61A1 GUN WITH M55A2 PROJECTILE AT +70°F (SECOND TEST)	
ROUND NO.	VELOCITY, ft/sec
1	3275
2	3290
3	- -
4	- -
5	3289
6	3270
7	3270
8	3325
9	3305
10	3291
11	3330
12	3303
13	3290
14	3328
15	3314
16	3304
17	3331
18	3282
19	- -

Remarks -
Gun Rate:
3588 rounds/minute
50 Yard Target Cloth
Group Size: 10½ inches x 12½ inches
Number of Holes: 24

TABLE 3. M61A1 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT +70°F

ROUND NO.	VELOCITY, ft/sec
689	3236
688	- -
687	3219
686	3207
685	3212
684	- -
683	- -
682	3217
681	- -
680	- -

Remarks -
50 Yard Target Cloth
Group Size: 10½ inches x 10½ inches
Number of Holes: 10

TABLE 4. M61A1 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT +160°F

ROUND NO.	VELOCITY, ft/sec
709	3265
708	3273
707	3277
706	3280
705	3291
704	3056
703	- -
702	- -
701	- -
700	-

Remarks -
50 Yard Target Cloth
Group Size: 42 inches x 13 inches
Number of Holes: 9

TABLE 5. M61A1 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT -65°F	
ROUND NO.	VELOCITY, ft/sec
699	3107
698	3063
697	3058
696	3030
695	3057
694	3066
693	- -
692	- -
691	- -
690	- -

Remarks -
50 Yard Target Cloth
Group Size: 10 inches x 7½ inches
Number of Holes: 10

TABLE 6. M39 GUN WITH M55A2 PROJECTILES AT +70°F	
ROUND NO.	VELOCITY, ft/sec
1	3188
2	3233
3	3259
4	3271
5	3282
6	3278
7	3287
8	3299
9	3300
10	3277
11	3284
12	3294
13	3295
14	3280
15	3306
16	3273

Remarks -
Gun Rate:
1277 rounds/minute
Average Velocity: 3275 ft/sec
Loose Mount Group Size not Taken

TABLE 7. M39 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT +70°F

ROUND NO.	VELOCITY, ft/sec
659	3104
658	- -
657	3106
656	2977
655	3113
654	3102
653	3111
652	3103
651	3075
650	3166

Remarks -
One projectile broke up on muzzle exit.
50 Yard Target Cloth
Number of Holes: 9

TABLE 8. M39 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT +160°F

ROUND NO.	VELOCITY, ft/sec
679	- -
678	- -
677	3189
676	- -
675	3020
674	- -
673	3238
672	•
671	•
670	•

Remarks:
•Rounds 672, 671, 670 were not fired due to cartridge case failing to exit.
One round broke up on muzzle exit.
50 Yard Target Cloth
Number of Holes: 6 (two key holes)

TABLE 9. M39 GUN WITH PLASTIC FRANGIBLE PROJECTILES AT 65°F

ROUND NO.	VELOCITY, ft/sec
669	2996
668	2964
667	2947
666	- -
665	2958
664	2856
663	2966
662	2955
661	2969
660	2915

Remarks -

One projectile hit (intact) the protective barrier.

50 Yard Target Cloth

There were four holes and all were in the top 4 inches of the target cloth.

1. M61A1 Gun

Tables 1 and 2 show the measured velocity for two bursts (24 rounds) of the M55A2 TP projectile. The measured velocity of the plastic frangible projectiles is given in Table 3 (+70°F), Table 4 (+160°F), and Table 5 (-65°F).

2. M39 Gun

Table 6 shows the measured velocity for 8 rounds of the M55A2 TP projectile. The measured velocity of the plastic frangible projectiles is given in Table 7 (+70°F), Table 8 (+160°F), and Table 9 (-65°F).

OBSERVATIONS

1. All rounds functioned in both the M39 and M61A1 gun at the three temperature conditions (-65°F, +70°F, and +160°F.

2. With the M61A1 gun, the dispersion of the plastic frangible projectile (at -65°F) on the 50 yard target cloth was considerably less than that of the standard TP ammunition, i.e., 10 x 14 inches versus 71/2 x 10 inches. (Compare Figures 6 and 7). However, at the high temperature extremes, the group was considerably larger (42 x 13 inches) see Figures 8 and 9.

3. There was no evidence of any intact projectiles in the target backstop, which was soft sand at a 45° angle with the horizontal (See Figure 4).

4. Fragments of Projectiles picked up at the target backstop provided the following observations:

a. It was noted that in several cases, groups of washers stayed together; however, they were not welded together and came apart easily in the hand (See Figure 10).

b. The plastic is being cold-formed to the extent that it is being squeezed between the washers, which are under compression due to acceleration. This occurs from the leading edge of the rotating band to the projectile base. (See Figures 11 and 12).

c. One almost intact plastic projectile body showed that gun gas is apparently escaping around the lands and grooves, thus darkening the projectile body forward of the rotating band (See Figures 12 and 13).

d. There is little evidence of a good bond between the projectile tip and the body, i.e., those fragments observed indicated an almost smooth, as molded, surface, with no indication that interfacial melting had taken place. (See Figures 11 and 13).

5. Fragments of projectiles picked up in front of the gun muzzle show that:

a. In some cases, gun gas was getting into the interior of the projectile. (See Figure 14).

b. The plastic body is breaking along the sharp edges of the octagonal platelet (independent of engraving by the lands and grooves of the barrel). See Figures 14 and 15).

6. The Three Projectiles that broke-up at the muzzle of the gun created a spray of high velocity steel platelets. (The protective barrier placed in front of the gun muzzle did not protect the Lumaline velocity screen due to the erratic flight path of the unstable platelets). (See Figure 16).

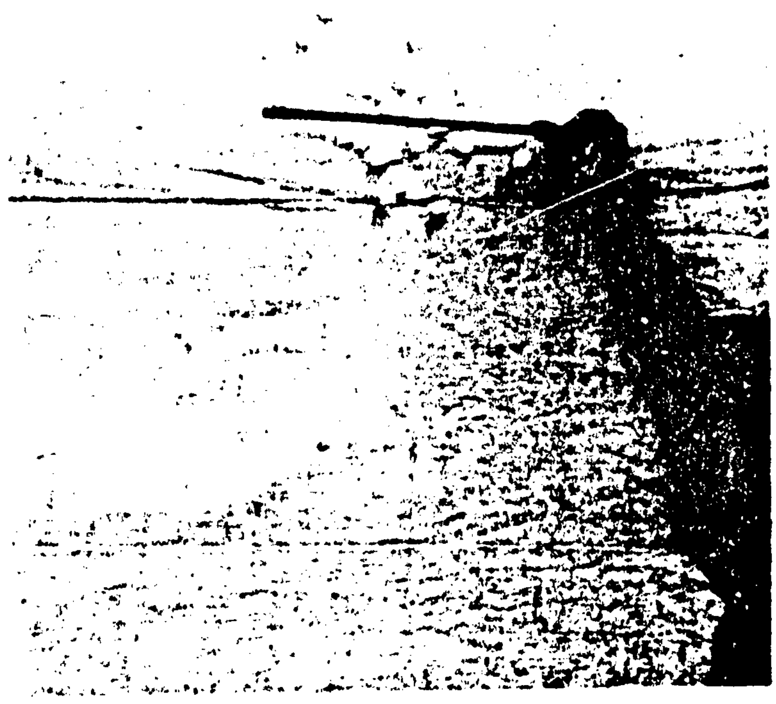

Figure 6. Twenty-four Rounds (One 5-round Burst and One 19-round Burst) of M55 A2 TP Projectiles

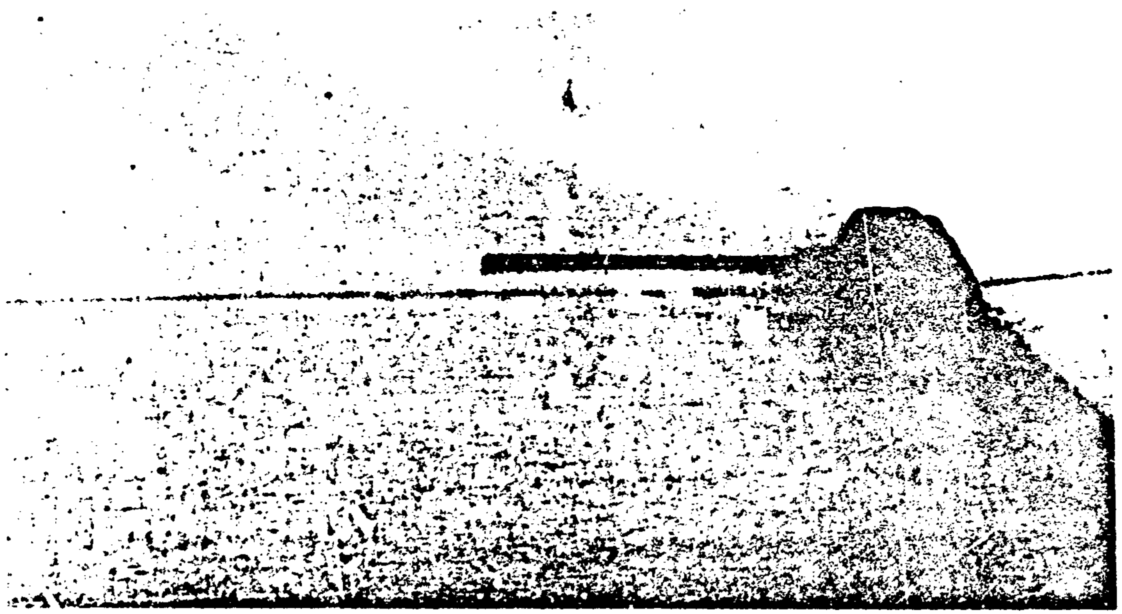

Figure 7. Ten Rounds of Plastic Frangible Projectiles (-65°F)

Figure 8. Ten Rounds of Plastic Frangible Projectiles (+70°F)

Figure 9. Nine Rounds of Plastic Frangible Projectiles (+160°F)

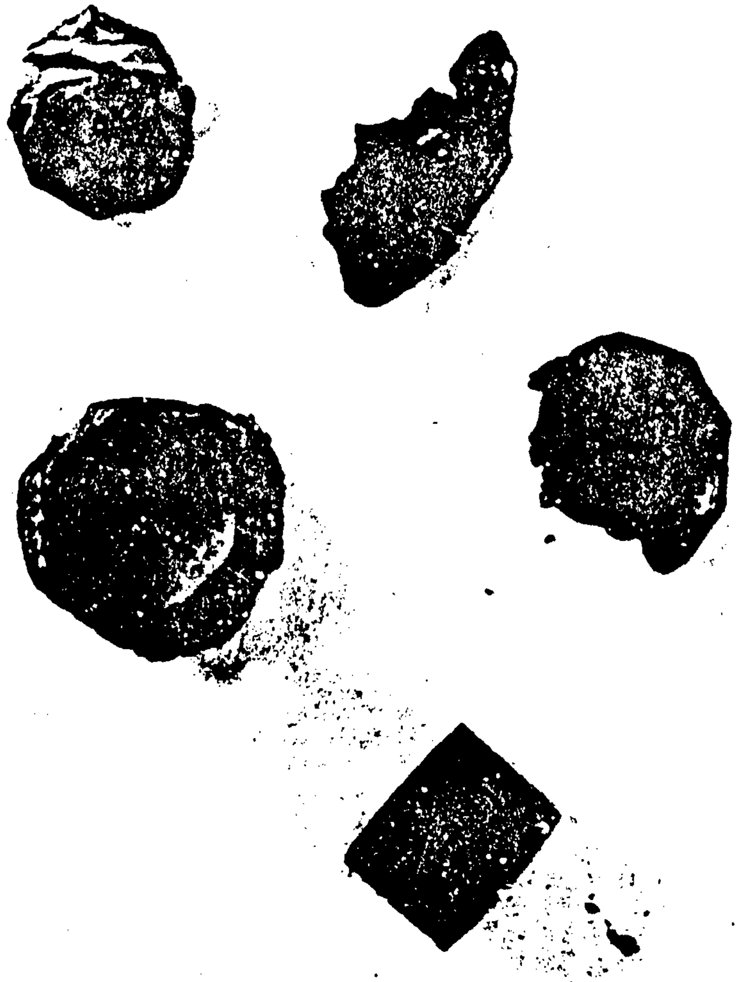

Figure 10. Metal Platelets of Plastic Frangible Projectiles Obtained at Target Backstop

Figure 11. Plastic Fragments of Plastic Frangible Projectiles Obtained at Target Backstop (Reverse)

Figure 12. Plastic Fragments of Plastic Frangible Projectiles Obtained at Target Backstop (Obverse)

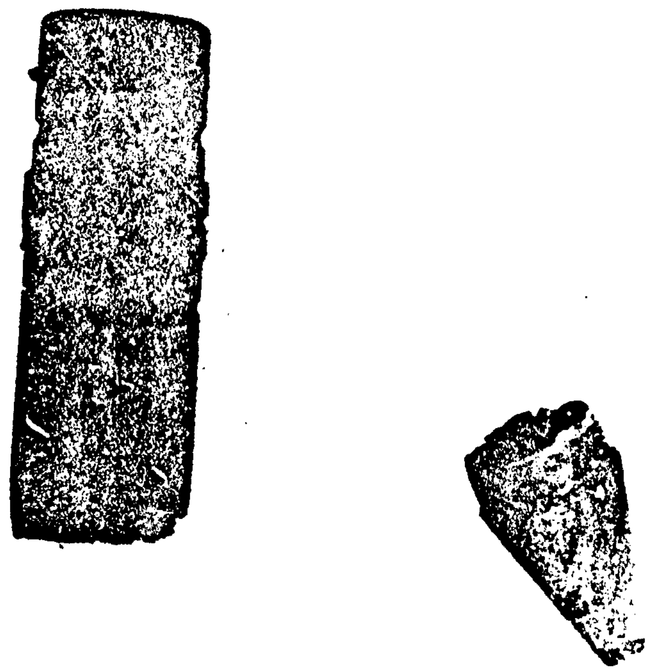

Figure 13. Plastic Sections

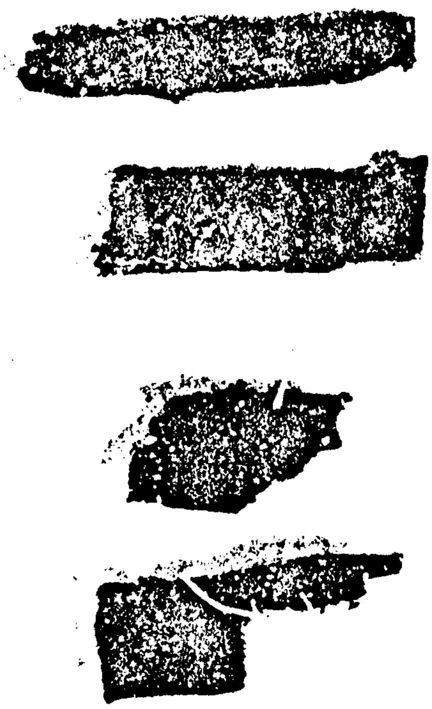

Figure 14. Plastic Fragments Obtained At Gun Muzzle (Reverse)

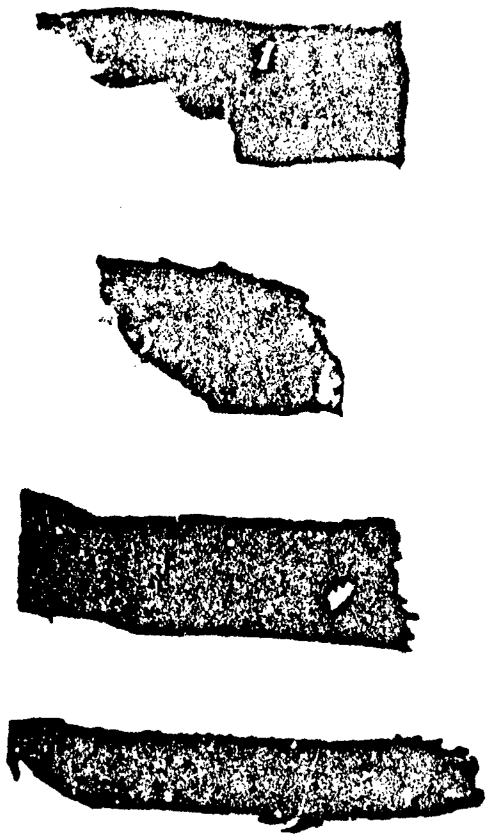

Figure 15. Plastic Fragments Obtained
At Gun Muzzle (Obverse)

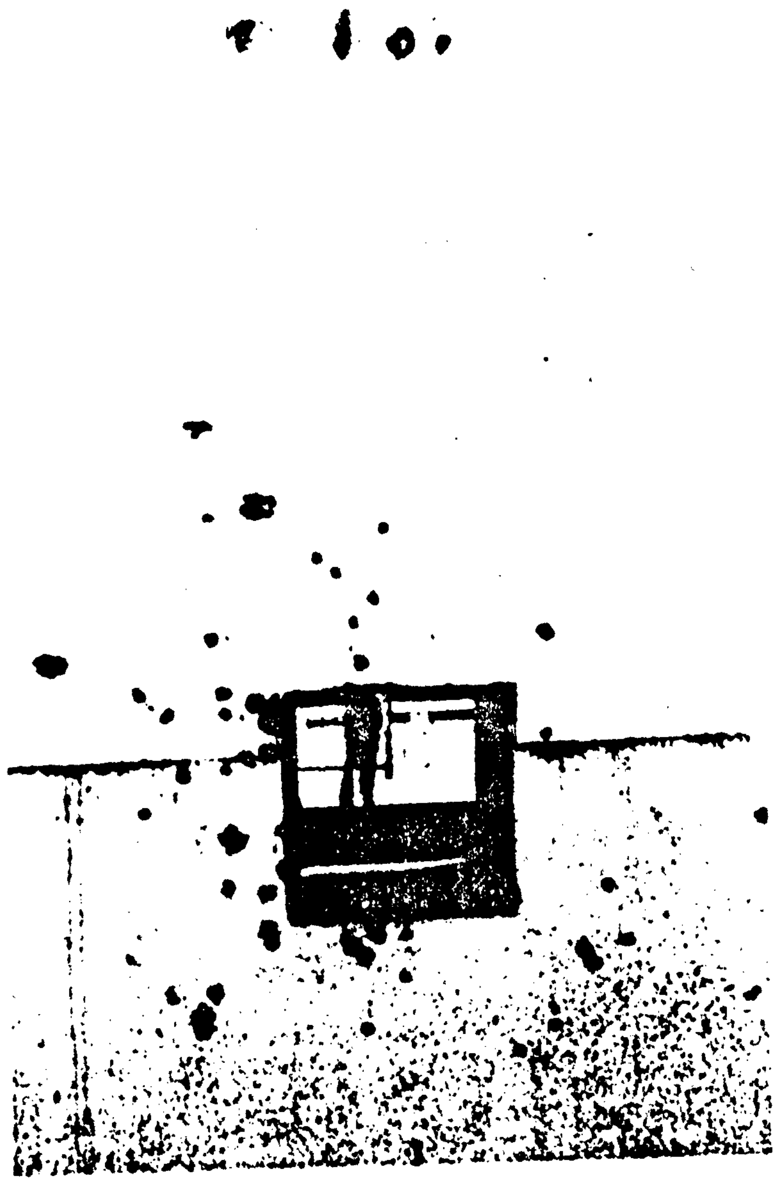

Figure 16. Protective Barrier Hit by Plastic Frangible Projectile That Broke Up At Gun Muzzle

CONCLUSIONS

1. The plastic frangible projectile presents no problems insofar as feed and gun function are concerned for both the M61A1 and M39 guns.

2. Premature projectile breakups occurring at the high temperature extreme and at ambient conditions appear to be the result of an inadequate bond between the projectile tip and body, coupled with a reduced elastic modulus and longitudinal stress risers located at the points of the octagon platelet column.

3. The gross deformation of the platelets on impact indicate a probable requirement for harder steel.

4. The gun gas escaping around the rotating band indicates a probable requirement for a rotating band of increased diameter.

5. The large dispersion at +160°F indicates an apparent need for a less deformable material in the rotating band area.

RECOMMENDATION

1. Should the current design be continued, a positive method should be devised to assure the integrity of the bond between the tip and projectile body.

2. An improved plastic encapsulation design should be devised.

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